Test Plan for Reciprocating Internal Combustion Engines

presented to:

ICCR Coordinating Committee

Houston, Texas

presented by:

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Topics

- Purpose of Briefing
- Context for Plan Development
- Test Plan Development Process
- Content of Test Plan
- Cost and Schedule

Purpose of Briefing

- Provide the Coordinating Committee background on the need for RICE emissions testing
- Inform the Coordinating Committee about the process to develop the test plan and the contents of the plan
- Provide the Coordinating Committee an opportunity to provide guidance relative to coordinating this testing with other Work Groups
- Inform the Coordinating Committee about the costs and schedule to conduct this Test Plan

Context for Plan Development (1)

- Coordinating Committee directed Work Groups to identify testing needs during March 1997 meeting
- EPA stressed that very limited funds would be available for HAPs emissions testing
- Work Group reviewed test reports for existing data
- Unexplained variability in emissions data included in ICCR Emissions Database for RICE
  - emission factors for formaldehyde emissions from natural gas-fired engines over 6 orders of magnitude
- Multiple emissions data gaps identified

Context for Plan Development (2)

- Work Group identified 3 possible goals for emissions testing under ICCR:
  1. acquire additional emissions data to assist the Work Group in determining the effectiveness of after-treatment control devices to reduce formaldehyde and other HAPs
  1. acquire additional emissions data to assist the Work Group in determining the effectiveness of combustion modifications to reduce formaldehyde and other HAPs;
  1. acquire additional emissions data that can assist the Work Group in determining typical emissions for engines throughout the operating range

Context for Plan Development (3)

- Work Group designed test plan around Goal #1 for the following reasons:
  - emissions data to demonstrate the effectiveness of possible MACT control devices for existing RICE is a data gap in the ICCR Emissions Database for RICE
  - Understanding the effects of combustion modifications on HAPs is in its infancy, and would require a very extensive research program to identify potential control techniques, along with confirming testing
  - EPA has endorsed the use of ICCR emissions testing dollars to achieve this goal.

Context for Plan Development (4)

- Work Group has further focused the plan to address the effectiveness of after-treatment control devices:
  - Effect on formaldehyde is primary focus
  - Effect on other HAPs is secondary focus
- Work Group added this focus for the following reasons:
  - Formaldehyde is a product of incomplete combustion and generally is the HAP emitted in the greatest quantities from RICE
  - Work Group was able to identify possible MACT for formaldehyde based on the results of emissions testing conducted by industry -- there is less understanding of possible MACT for other HAPs
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Process to Develop Test Plan

(1 of 4)

- Emissions Subgroup formed and assigned task to identify testing needs for RICE Work Group
  - 19 members, all stakeholders represented
- First step: Identify pollutants to be tested
  - Presented to Coordinating Committee in July, comments on pollutants accepted until September 5
- Second step: Identify test methods to use

Process to Develop Test Plan
(2 of 4)

- Third Step: Address Engine Considerations:
  - Operating Conditions
    - » Based on industry experience with criteria pollutants, such as NOx, believe operating conditions can affect HAP emissions and efficiency of controls
    - » Need to conduct testing over full operating range
      - Need person with knowledge of engine operations on site to establish condition of engine
      - Need to collect adequate operating parameter data to relate operating conditions and emissions

Process to Develop Test Plan
(3 of 4)

- Engine Considerations (continued)
  - Diversity of Existing Engine Population
    - » Over 3,000 possible combinations
      - Operating cycle (spark ignition or compression ignition)
      - Fuel
      - Scavenging cycle (2-stroke or 4-stroke)
      - Air-to-fuel ratio (rich or lean)
      - Make and model
      - Size
      - Driven equipment and application
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Process to Develop Test Plan
(4 of 4)

- Work Group has put a lot of effort into development of this Test Plan
  - Plan developed over past 8 months
    - » Numerous conference calls to develop content
    - » Experts provided input on key components:
      - Testing and Monitoring Protocol Work Group
      - Engine and other testing experts
    - » Components of plan reviewed at May, September, & October Work Group meetings
    - » Multiple drafts of plan reviewed by Work Group
- Work Group consensus on final plan achieved on October 30, 1997

Content of Test Plan

- Four Tests Proposed
- Components of Tests:
  - Fuels, Engines, and Emission Controls to be Tested
  - Matrix of Operating Conditions
  - Pollutants to be Tested
  - Test Methods to Quantify Pollutants
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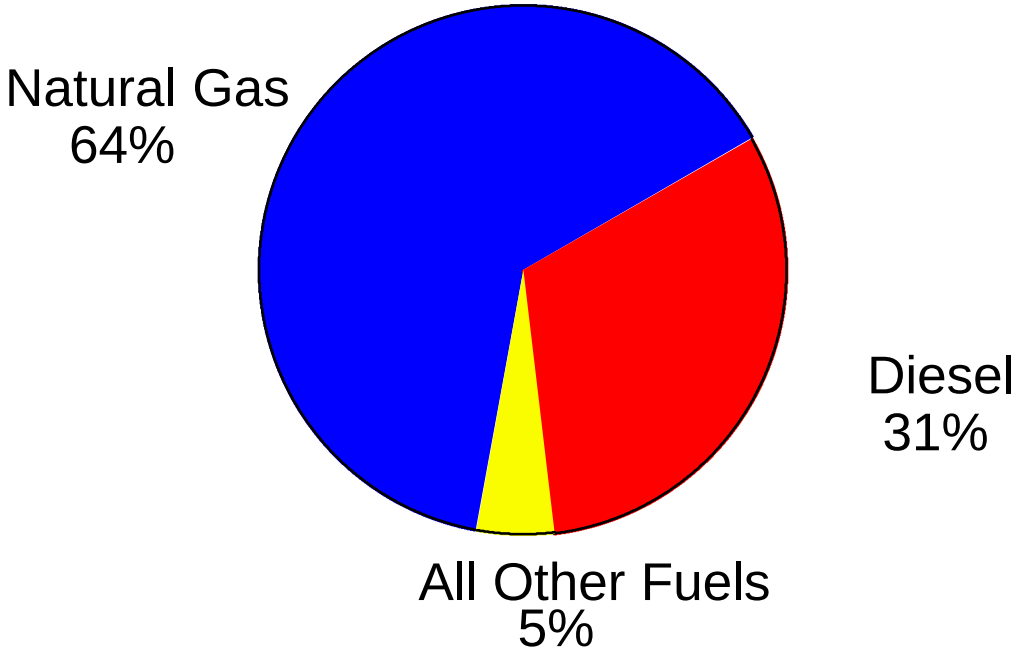
Fuels to be Tested

- Two most popular fuels for stationary RICE:
  - Diesel Fuel and Natural Gas



Source: ICCR Population Database for Reciprocating Internal Combustion Engines v 2.0

Engines to be Tested

- Diesel (CI)
  - Caterpillar 3500
- Natural Gas (SI, 2- and 4-stroke, rich and lean)
  - 2-stroke, lean-burn:
    - » Clark TLA, turbocharged
  - 4-stroke, lean-burn
    - » Waukesha 7042 GL, turbocharged
  - 4-stroke, rich-burn
    - » Ingersoll Rand KVG, naturally aspirated

Controls to be Tested

- Focus on devices identified as possible maximum achievable control technology (MACT)
  - Oxidation catalysts for lean-burn engines
  - Non-selective catalytic reduction (NSCR) three-way catalysts for rich-burn engines

Engines	Control Device
Clark TLA Turbocharged	oxidation catalyst
Caterpillar 3500 Series Turbocharged	oxidation catalyst
Waukesha 7042 GL Turbocharged	oxidation catalyst
Ingersoll Rand KVG Naturally Aspirated	non-selective catalytic reduction (NSCR)

Matrix of Operating Conditions

- Work Group plans to conduct testing over multiple operating conditions:
  - Four corners of torque/speed envelope
  - Air-to-fuel ratio sensitivity
  - High speed and low load
  - Low speed and high load
  - Air manifold temperature sensitivity
  - Jacket water temperature sensitivity
  - Engine balance sensitivity

Pollutants to be Tested

- Both criteria pollutants and HAPs to be tested before and after pollution control devices
- Criteria Pollutants:
  - carbon monoxide (CO), nitrogen oxides (NOx), total hydrocarbons (THC), particulate matter (PM) (diesel only)
- HAPs:
  - BTEX (benzene, toluene, ethylbenzene and xylene)
  - Aldehydes (formaldehyde, acetaldehyde acrolein)
  - Naphthalene, 1,3-butadiene, PAHs
  - n-Hexane (diesel only)
  - metals (diesel only)

Test Methods

- Test methods selected that will provide direct measurement and reporting of pollutant concentrations on-site, whenever possible
  - Direct Interface Gas Chromatograph/Mass Spectograph (GCMS) (BTEX, 1,3-butadiene, hexane)
  - Fourier Transform Infrared (FTIR) (aldehydes, NOx, CO)
  - EPA method 25A (THC and methane)
  - ISO 8178 (particulate matter)
  - CARB 429 (naphthalene and PAHs)
- Testing to be conducted to achieve lowest practical detection limits for all compounds
- Fuel testing for metals

Possible Test Sites

- All natural gas-fired units:
  - Engines and Energy Conversion Laboratory, Colorado State University, Fort Collins, Colorado
- Diesel unit:
  - to be determined

Costs and Next Steps

- Cost to Conduct Test Plan:

  $610,000*

- Next Steps:

  - November 1997 — Work Group to submit Plan to EPA and request funding
  - Fall 1997 — Work Group to confirm test sites
  - Spring 1998 — EPA Contractor to conduct testing

*Testing and Monitoring Protocol Work Group provided cost estimate to conduct plan.